Appendix A

California Facilities and Greenhouse Gas Emissions Inventory – High-Global Warming Potential Stationary Source Refrigerant Management Program

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1. Introduction

The proposed Refrigerant Management Program regulation for the management of stationary equipment refrigerants was developed by the California Air Resources Board (ARB) staff to reduce the emissions of high global warming potential (GWP) greenhouse gases (GHG) used in commercial and industrial refrigeration and air-conditioning equipment. This regulation is being developed as an early action measure as part of implementing Assembly Bill 32, the Global Warming Solutions Act of 2006. This program aims to minimize emissions of high-GWP refrigerants from stationary refrigeration and air-conditioning equipment through facility registration, leak detection and monitoring, leak repair, system retrofit and retirement, required service practices, and record-keeping and reporting. ARB is also working with the California Energy Commission to develop specifications for new refrigeration and air-conditioning equipment, which will be addressed in the next round of revisions to Title 24 regulations (California Building Standards Code, which contains the Building Energy Efficiency Standards).

High-GWP refrigerants include chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), and hydrofluorocarbons (HFC). CFC and HCFC are classes of ozone depleting substances (ODS). HFC are non-ozone depleting substitutes. Both ODS and HFC have very high global warming potentials, ranging between 500 and 10,000 times more potent than carbon dioxide (CO_2).

ODS production is controlled under the Montreal Protocol as a result of concerns about stratospheric ozone depletion, but emissions are not controlled. The underlying assumption of the Montreal Protocol is that the gases produced will eventually be emitted. However, for some end uses there can be a considerable time lag between gas production and emission.

High-GWP GHG can generally be categorized as Kyoto gases or Non-Kyoto gases. Kyoto gases are those that pertain to the Kyoto Protocol including CO_2, HFC, methane, nitrous oxide, perfluorocarbons, and sulfur hexafluoride. Non-Kyoto gases include the ODS Montreal Protocol gases, and several miscellaneous gases not covered under either treaty.

As part of its assessment of the feasibility of potential regulations, the ARB must consider cost-effectiveness. To develop such an estimate requires a characterization of the baseline emissions as well as the potential emission reductions from the proposal. It also requires that the number and types of businesses affected as well as compliance costs be identified. This appendix describes the methodology used to determine:

- Types and numbers of businesses affected;

- Types and numbers of refrigeration and air-conditioning (R/AC) systems affected;
- Baseline refrigerant GHG emissions from a current business-as-usual (BAU) scenario; and
- Emission reductions as a result of implementation of the proposed rule.

The results of the analysis summarized in this appendix are used as the basis to calculate costs of the proposed rule, which are presented separately in Appendix B.

2. Summary of Results

ARB staff characterized the types of facilities, and existing and projected number of facilities that utilize R/AC systems of different sizes in California statewide. Facility numbers were estimated for three refrigerant charge size categories based on the amount of refrigerant contained within individual R/AC systems, in accord with the proposed implementation requirements:

Refrigerant Charge Size Categories:

- Small: 50 pounds or greater but less than 200 lbs (50-<200 lbs);
- Medium: 200 pounds or greater, but less than 2,000 lbs (200-<2,000 lbs); and
- Large: 2,000 pounds or greater (≥2,000 lbs).

Thresholds were determined based upon the potential of emissions from leaking R/AC systems, with the larger systems having potentially the greatest emissions. The minimum charge level of 50 pounds was based on the U.S. EPA Section 608 of the Clean Air Act threshold, and the SCAQMD Rule 1415 threshold; which in turn are based on the low leak rates and emissions from systems less than 50 pounds. Systems with less than 50 pounds of refrigerant are generally sealed systems with relatively low leak rates (less than five percent per year). Therefore, systems with more than 50 pounds of refrigerant account for the majority of refrigerant emissions from the stationary sector.

The 200-pound threshold was set to ease rule requirements for systems with less risk of large GHG emissions; as systems less than 200 pounds (but more than 50 pounds) are composed of refrigerant condensing units and unitary AC systems that generally leak less than systems greater than 200 pounds, such as centralized refrigeration systems.

The 2,000 pound threshold was based upon emissions data from the Rule 1415 dataset, which shows that very large refrigerant systems with 2,000 pounds or more of refrigerants have relatively high leak rates and large refrigerant charge sizes, which combine to form the potential for the greatest emissions. (Although it bears noting that large chillers (containing 2,000 pounds or more refrigerant) used for air conditioning tend to leak less than large refrigeration systems used in retail food facilities.) Staff considered setting this threshold as low as 600 pounds to reflect some of the goals of the European Union F-Gas regulations, but setting the large system category to 600 pounds would have included a large number of facilities where some proposed rule requirements such as the installation of automatic leak detection systems may not have resulted in any significant reductions of refrigerant emissions.

Note that for the proposed rule, the term system means any refrigeration or air-conditioning equipment with a single refrigerant circuit that is intended for the purpose of cooling or freezing, or providing cooling in order to control heat or humidity in facilities. A system could have multiple compressors and evaporators and still be considered a single system, if they are connected by a single refrigerant circuit.

The following table is a summary of the current number of facilities potentially subject to the rule, showing the lower and upper ranges of facilities.

Table 1. Number of facilities subject to rule, shown by refrigerant charge size category.

Estimate Range[1]	# Facilities w/ R/AC Equip ≥ 50 lbs, < 200 lbs (Small)	# Facilities w/ R/AC Equip ≥ 200 lbs, < 2,000 lbs (Medium)	# Facilities w/ R/AC Equip ≥ 2,000 lbs (Large)	# Total Facilities
Lower	128,000	56,000	9,000	193,000
Upper	173,000	76,000	11,000	260,000
Average	150,000	66,000	10,000	226,000

Note that the number of facilities as shown represents facilities containing one or more pieces of R/AC equipment greater than the small, medium, and large refrigerant charge thresholds – the table does not reflect the actual number of pieces of R/AC equipment, which is discussed in a separate section. Generally, each facility with “small” R/AC equipment contains about five small R/AC systems. Each facility with “medium” R/AC equipment contains about five medium R/AC systems, and each facility with “large” R/AC equipment contains about two large R/AC systems.

Baseline 2010 emissions from R/AC equipment with refrigerant charges greater than 50 pounds are about 10.6 million metric tonnes of CO_2 equivalent

[1] An estimated range is the result of the imprecise estimate of the number of office buildings potentially affected by the proposed rule. The empirical refrigerant emissions data was linked to business types identified by North American Industry Classification System (NAICS) codes, which did not always translate adequately to general facility types (such as offices, supermarkets, warehouses, etc.). When empirical data was extrapolated into statewide estimates, the narrow range of reasonable facility estimates for office buildings was multiplied into a statewide range of plus or minus 22,500 office buildings. ARB staff used the average between the lower and upper range of facilities as the most reasonable estimate. Detailed discussions on the methodology used to determine facility numbers is included in subsequent sections of this appendix.

($MMTCO_2E$) from HFC and 17.2 $MMTCO_2E$ from ODS (27.8 $MMTCO_2E$ total), which are expected to increase under BAU by 2020 to 24.6 $MMTCO_2E$ from HFC and 6.1 $MMTCO_2E$ from ODS (30.7 $MMTCO_2E$ total).

In aggregate, the proposed rule is expected to result in GHG emission reductions of approximately 50 percent (compared to BAU) from stationary R/AC systems affected by the rule.

HFC emission reductions in 2020 are estimated to be 12.4 $MMTCO_2E$, with another 3.1 $MMTCO_2E$ in reductions from ODS (15.5 $MMTCO_2E$ GHG reductions total).

The following table is a summary of emissions in the baseline year of 2010, and those projected in 2020 under both BAU in the absence of the proposed regulation, and with implementation of the proposed regulations.

Table 2. Potential emissions and emission reductions associated with the proposed regulation in 2010 and 2020. All emissions expressed in $MMTCO_2E$.

	HFC Emissions			**ODS Emissions**			**Total (HFC+ODS)**		
Emissions Scenario[2]	Low	High	**Ave.**	Low	High	**Ave.**	Low	High	**Ave.**
2010 Baseline (BAU) Emissions	8.9	12.2	**10.6**	14.6	19.8	**17.2**	23.6	32.0	**27.8**
2020 (BAU) without Rule in place	20.9	28.3	**24.6**	5.2	7.1	**6.1**	26.1	35.4	**30.7**
2020 Post-implementation of Rule	10.4	14.1	**12.2**	2.6	3.5	**3.1**	13.0	17.6	**15.3**
2020 Emission Reductions (BAU minus post-rule emissions)	10.5	14.2	**12.4**	2.6	3.6	**3.1**	13.1	17.8	**15.5**

This analysis does not quantify potential emission reductions directly from equipment with less than 50 pounds of high-GWP refrigerant charge. The proposed regulation would require more stringent service practices, regardless of the charge size of the equipment. As a result, refrigerant emissions that would occur in the course of servicing residential air-conditioning equipment, for example, would be expected to decrease as a result of the rule, but are not quantified in this analysis. ARB will continue to evaluate additional regulatory and market-based incentives, such as an upstream mitigation fee, to promote comprehensive control of refrigerant emissions regardless of equipment size.

[2] Each emissions scenario is estimated using a range of facility numbers. The lower end of the estimated emissions range (low) is calculated by using the lowest estimated number of facilities potentially affected by the rule. The upper end of the emissions range (high) is calculated by using the highest number of facilities potentially affected by the rule. The average emissions estimate (ave.) is calculated by using the average number of facilities between the lower and upper ranges.

3. Methods

As discussed in great detail later, statewide estimates of the number of facilities using R/AC equipment with greater than 50 pounds of refrigerant were calculated and refined using several data sources. Facility number estimates were refined using additional data sources whenever possible to reduce known sources of bias for specific facility types.

Based on all available data, emissions estimates were determined for several unique R/AC system groups. R/AC system types were identified to include:

Refrigeration Systems

- Process Cooling (Industrial cooling, industrial process cooling, industrial refrigeration)
- Cold Storage
- Centralized Systems (also called DX [Direct Expansion]) systems or parallel rack systems)
- Condensing Units (also called remote condensing units)

Air-conditioning (AC) Systems

- Centrifugal Chillers
- Packaged Chillers (also called positive displacement chillers, which include sub-types of chillers: reciprocating, screw, and scroll)
- Unitary AC (includes Split AC Systems [ducted and non-ducted]; Roof-top Units; Packaged AC Systems)

Each unique refrigerant charge size category and system type create a R/AC System Group that defines the basis for all analysis. The following summarizes typical uses of R/AC Systems:

- Process cooling, while technically a function and not a system, is the term commonly used to describe customized, built systems containing very large refrigerant charges (3,500 pounds on average) used in food and drink processing (brewing, distilling, dairy, and soft drink industries), and in industrial refrigeration in the chemical, petrochemical, and pharmaceutical industries.
- Cold storage is also more technically a function, and not a system, but is the generally accepted term for custom built refrigeration systems with greater than 200 pounds of refrigerant, used to cool large storage areas at temperatures between minus 20º F and 50º F, primarily for food storage.
- Centralized systems are commonly used in supermarkets and grocery stores to cool food in display cases and walk-in-coolers. Centralized systems may contain multiple compressor racks in a central location, where the refrigerant circulates from the central location to retail floor

space. Centralized systems tend to be leaky because of the many feet of refrigerant piping and number of connections necessary for these systems.

- Condensing units are similar to a smaller version of a centralized system, but consist of only one compressor rack that may cool a single walk-in-cooler or one or two display cases. Generally used in food retail businesses such as convenience stores, medium-sized to smaller-sized grocery stores, and restaurants.
- Chillers, also known as water chillers, cool water or heat transfer fluids for air conditioning in retail and commercial buildings. The two primary types of chillers are centrifugal chillers and packaged chillers, which differ primarily by the mechanical system used. Packaged chillers tend to be smaller and more leak-tight than centrifugal chillers.
- Unitary AC systems are self-contained cooling units used for air conditioning in buildings. The average unitary AC system contains less than 100 pounds of refrigerant.

After numbers of facilities and R/AC systems were estimated, the emissions from these sources were calculated from R/AC equipment usage patterns and annual leak rate data provided in the rule 1415 dataset.

Estimates of the distribution of R/AC equipment using specific HFC and ODS refrigerants were obtained from the United States Environmental Protection Agency (U.S. EPA) Vintaging Model and applied to the rule 1415 dataset. Refrigerant use distributions were adjusted to reduce a known bias in the rule 1415 data set generated by a requirement to report refrigerant use patterns for only refrigeration systems utilizing ODS refrigerants.

Summarized data was developed for each R/AC system group and GHG emissions in $MMTCO_2E$ were calculated using the following equation:

Emissions ($MMTCO_2E$) =

*Number of facilities * systems/facility * average charge (lbs)/system * 4.54^{-10} lbs per MMT * GWP of refrigerant * average percent of systems leaking during any given year * average percent of charge lost from leaking systems*

Where:

- Number of facilities includes all facilities with a R/AC system potentially subject to the rule. The number of facilities used was the average number, unless an upper and lower range of emission estimates were desired. In addition to the number of facilities, the types of businesses affected were also analyzed.

- Systems per facility factor was an average number of systems (specific to R/AC equipment type and refrigerant charge size) within a facility. The factor was developed by dividing the total number of a specific type of R/AC equipment and charge size category by the total number of facilities containing those R/AC systems.
- The average charge per system is the average number of pounds of refrigerant for a given R/AC group.
- 4.54^{-10} lbs per MMT is the conversion factor to convert pounds of refrigerant to million metric tons of refrigerant (which enables calculation of GHG emissions in million metric ton-equivalents of carbon dioxide).
- GWP of refrigerant is the global warming potential of the refrigerant compared to CO_2 over a 100-year time horizon. For consistency with the method used to calculate California's GHG baseline emissions for AB 32, the Intergovernmental Panel on Climate Change (IPCC) Second Annual Report was used as the source of GWP values. Where GWP values had not yet been calculated for specific refrigerants, the values from the IPCC Third Annual Report were used. Multiplying the quantity of refrigerant in million-metric tons by the GWP yields emissions in terms of million metric tons of carbon dioxide equivalent ($MMTCO_2E$). In order to use the proper GWP for project BAU emissions in 2010 and 2020, it was necessary to also use the U.S. EPA Vintaging Model's estimated ratio of R/AC systems that use HFC refrigerants compared to R/AC systems that use ODS refrigerants (and the comparative share of all HFC and ODS refrigerant use by both pounds and $MMTCO_2E$). After individual GWPs were assigned to specific equipment, a weighted-average GWP was used for each category of R/AC equipment (large centralized systems, medium centralized systems, small unitary AC systems, etc.).
- The average percent of systems leaking during any given year is the total number of leaking systems divided by the number of all systems. This factor was calculated for all systems within a charge size (small, medium, large), and further refined by calculating the percent of leaking systems for each specific type of system within the size category (large centralized systems, medium centralized system, large cold storage, medium cold storage, small unitary AC systems, etc.).
- The average percent of charge lost from leaking systems is the amount of refrigerant lost from leaking systems divided by the total charge capacity of those systems that leak.
- Percent of systems leaking during any given year multiplied by the average percent of charge lost from leaking systems yields the annual average leak rate across all systems within the category. When the annual average leak rate is multiplied by the total quantity of charge, the product is the annual amount of refrigerant emissions resulting from leaks.

The following sections describe the data sources used to develop the emission factors, and how the emission factors were developed.

A. Data Sources used to develop Emission Factors:

Data sources used to develop the emission factors shown in the previous section are briefly described below. Additional details on how the data sources were used to develop emission factors are included in subsequent sections of this appendix.

South Coast Air Quality Management District (SCAQMD) Rule 1415 dataset: As part of the SCAQMD Rule 1415 (Reduction of Refrigerant Emissions from Stationary Refrigeration and Air Conditioning Systems), all facilities using R/AC equipment with an ODS refrigerant charge greater than 50 lbs are required to submit a biennial report on the refrigerant charge of each piece of equipment and the amount of refrigerant used each year. The amount of refrigerant used each year is the amount added to existing systems, and is assumed to represent leaked refrigerant emissions. Only facilities with R/AC equipment utilizing ODS refrigerants are required to report under Rule 1415.

Biennial reports include facility descriptions, including standard industrial classification (SIC) codes and numbers and types of R/AC equipment used. The description of each R/AC system includes the equipment refrigerant charge sizes, and refrigerant use data.

The Rule 1415 data served as the primary source of data to estimate the following: facility numbers potentially subject to the rule, types of businesses affected, number and types of R/AC systems per facility, average charge size of R/AC systems, types of refrigerants used, average percent of systems leaking, and average rate of refrigerant loss when leaks occur.

The Rule 1415 biennial reports were selected as the primary source of data for emissions estimate because they were the most comprehensive collection of data available specific to actual refrigerant usage and losses, which gave it the distinction of being the best source of empirical data for refrigerant emissions in California. The Rule 1415 data were available for six years (reporting years 1999 through 2005) and consisted of approximately 16,000 records.

Energy Information Administration 2003 Commercial Buildings Energy Consumption Survey (CBECS survey): The national Commercial Buildings Energy Consumption Survey was conducted to collect information on the number of commercial buildings nationwide and to characterize energy related building characteristics. As a part of this survey a data table is available that outlines the estimated number of buildings within several broad building activity types (e.g., office buildings and office complexes) that utilize comfort cooling equipment including packaged air-conditioning units, central chillers, and district chilled water. A “NAICS code crosswalk” including a list of three digit North American Industry Classification System (NAICS) codes which are representative of the types of facilities characterized by each of the principal building activities is also provided.

The CBECS report provided characterizations of commercial heating, ventilation, and air-conditioning (HVAC) equipment use for broad facility categories, including office buildings and office complexes. Using this dataset, the number of offices in California using HVAC equipment with refrigerant charges greater than 50 lbs, 200 lbs, and 2,000 lbs were cross-checked against the Rule 1415 dataset and its facility extrapolations.

Data obtained from the CBECS report was more precise than facility number estimates obtained from the NAICS codes mapped from the Rule 1415 dataset because it provided a breakdown of office building categories by the types of HVAC equipment used. This enabled more accurate assignment of the proportion of office buildings assigned to each refrigerant charge size threshold.

California Commercial End-Use Survey (CEUS): An annual survey administered by the California Energy Commission, which collects a wide variety of data on the energy use of commercial buildings in California. The CEUS survey data from 2007 was used to complement Rule 1415 data and provided an independent source of data for statewide numbers and types of facilities affected by potential regulations; and for numbers, types, and cooling capacities of R/AC systems used in commercial facilities. The CEUS data was also used as a cross-check to Rule 1415 data extrapolations to statewide facility numbers.

ARMINES - Inventory of Direct and Indirect GHG Emissions from Stationary Air conditioning and Refrigeration Sources, with special Emphasis on Retail Food Refrigeration and Unitary Air Conditioning – Provisional Final Report, July 2008 (ARMINES 2008 report): The provisional final report provided by ARMINES (principal investigator, Denis Clodic) as a part of their contract with ARB provides comprehensive inventories that are California-specific on the numbers and types of retail food facilities (supermarkets, grocery stores, restaurants, etc.), as well as the numbers and types of refrigeration equipment used by the facilities. Data was obtained using surveys and facility visits in California. Additional reported data included inventories on numbers and types of commercial refrigeration systems used in cold storage, industrial process cooling, and air cooling in businesses.

ARMINES survey data was used as the primary source of information for numbers of facilities within the following business type categories: retail food, pharmacies, and hotels/motels. ARMINES data was also used as a reference for average annual leak rates from R/AC equipment.

U.S. EPA Vintaging Model. The U.S. EPA Vintaging Model was developed to estimate nationwide patterns of GHG emissions of HFCs, perfluorocarbons, CFCs, and HCFCs from all major emission sources, including refrigerant usage. This model is not publically available, so a combination of reference information was used to gather data from the model. This information represents three separate versions of the Vintaging Model, which may introduce some discrepancies in the resulting calculations. ARB is working with the U.S. EPA to obtain the most current, published or publishable, data from the Vintaging Model to use in the final version of this Rule. Three U.S. EPA Vintaging Model data sources were used:

1) National emission estimates from the U.S. EPA's Vintaging Model for R/AC systems were provided to ARB for year 2006, and also projected emissions for years 2010 through 2020. National estimates were scaled down to California's portion of the national population.

2) U.S. EPA 2003 informational paper "Modeling Emissions of High Global Warming Potential Gases from Ozone Depleting Substance Substitutes (U.S. EPA Vintaging Model)" by Godwin D. S., Van Pelt M. M. and Peterson K. Describes the assumptions and methodologies used in the Vintaging Model to estimate High-GWP greenhouse gases, including refrigerants.

3) Vintaging Model, EPA ODS Tracking System, and AFEAS Comparison for Common Refrigerants (U.S. EPA 2007). Consists of Vintaging Model technical summaries of R/AC system numbers, average annual leak rates of R/AC equipment, refrigerant emissions, average charge size, types of refrigerant used, and trends in R/AC systems and refrigerant uses. Used to supplement, refine, and act as a cross-check for Rule 1415 data. Summaries are provided for the following R/AC categories:

- ODS and ODS Substitutes in U.S. Commercial Refrigeration (includes centralized systems).
- ODS and ODS Substitutes in the Commercial Unitary AC End Use.
- ODS and ODS Substitutes in the U.S. Cold Storage.
- ODS and ODS Substitutes in the U.S. Industrial Process Refrigeration (IPR).
- ODS and ODS Substitutes in the Centrifugal Chiller End-Uses.
- ODS and ODS Substitutes in the Positive Displacement Chiller End-Uses.

US Census Bureau NAICS code website: The US Census Bureau published an online guide to mapping SIC codes to 2002 NAICS code on their website: http://www.census.gov/epcd/www/naics.html. This resource was used to help translate, or map the SIC codes provided in the Rule 1415 data to the currently used NAICS codes. NAICS codes are the "common denominator" used to describe facilities, and these had to be determined to extrapolate the number of facilities within the Rule 1415 dataset to a statewide number of facilities.

US Census Bureau censtats database: The US Census Bureau publishes statewide facility number estimates for individual NAICS codes in California on their website: http://censtats.census.gov/cbpnaic/cbpnaic.shtml. This resource was used to estimate the statewide number of facilities for individual NAICS codes.

Intergovernmental Panel on Climate Change Second Assessment Report (IPCC SAR), and Third Assessment Report (IPCC TAR): Initially developed to address potential strategies to reduce or avoid climate change worldwide, the second and third assessment IPCC reports include estimates of the global warming potentials for common refrigerants.

2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC GHG Guidelines): IPCC developed guidelines in 2006 for estimating national GHG inventories. Volume 3 (Industrial Processes and Product Use), Chapter 7 (Emissions of Fluorinated Substitutes for Ozone-Depleting Substances) includes a range of estimates of charge (kilograms of refrigerant), lifetime of equipment (years), annualized refrigerant emissions, and recovery efficiency for several types of R/AC equipment. Relevant types of R/AC equipment reported include: stand-alone commercial refrigeration, medium and large commercial refrigeration, industrial refrigeration (including food processing and cold storage), chillers, and commercial air conditioning. This document contained information on the proper methodology to follow when estimating refrigerant GHG emissions. These methodologies helped inform and direct the ARB methodology used to estimate GHG emissions in California from stationary R/AC equipment.

IPCC/TEAP (Intergovernmental Panel on Climate Change [IPCC] and Technology and Economic Assessment Panel [TEAP] Special Report on Safeguarding the Ozone Layer and the Global Climate Systems, 2005. Report provides the scientific context required for consideration of alternatives to ODS, potential methodologies for assessing options, and technical issues related to GHG emission reduction opportunities for several ODS emission sectors, including refrigeration and air conditioning. This document was used as a basic source of technical information on commercial refrigeration and air conditioning; providing an overview of relevant technologies, emission patterns and trends, ranges of annual leak rates for R/AC equipment, and consideration of improving containment, recovery, and recycling of refrigerants. This document was also the primary source of information for estimated minimum achievable lower leak rates using best management practices for R/AC equipment. The lower feasible and achievable leak rates are used to estimate potential emission reductions.

United Nations Environment Programme 1998 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, October 1998; Annex III-Refrigerant Data (UNEP 1998): Comprehensive report on the types of refrigerant and cooling systems used internationally, GHG emissions from these sources, and trends in refrigerant usage (transition of ODS to HFC and other refrigerants), and numbers and types of R/AC equipment. Detailed summaries on all major types of R/AC equipment used commercially. Used to compare average refrigerant leak rates of R/AC equipment (as a “reasonable” baseline) based on international data, with the average refrigerant leak rates reported under Rule 1415.

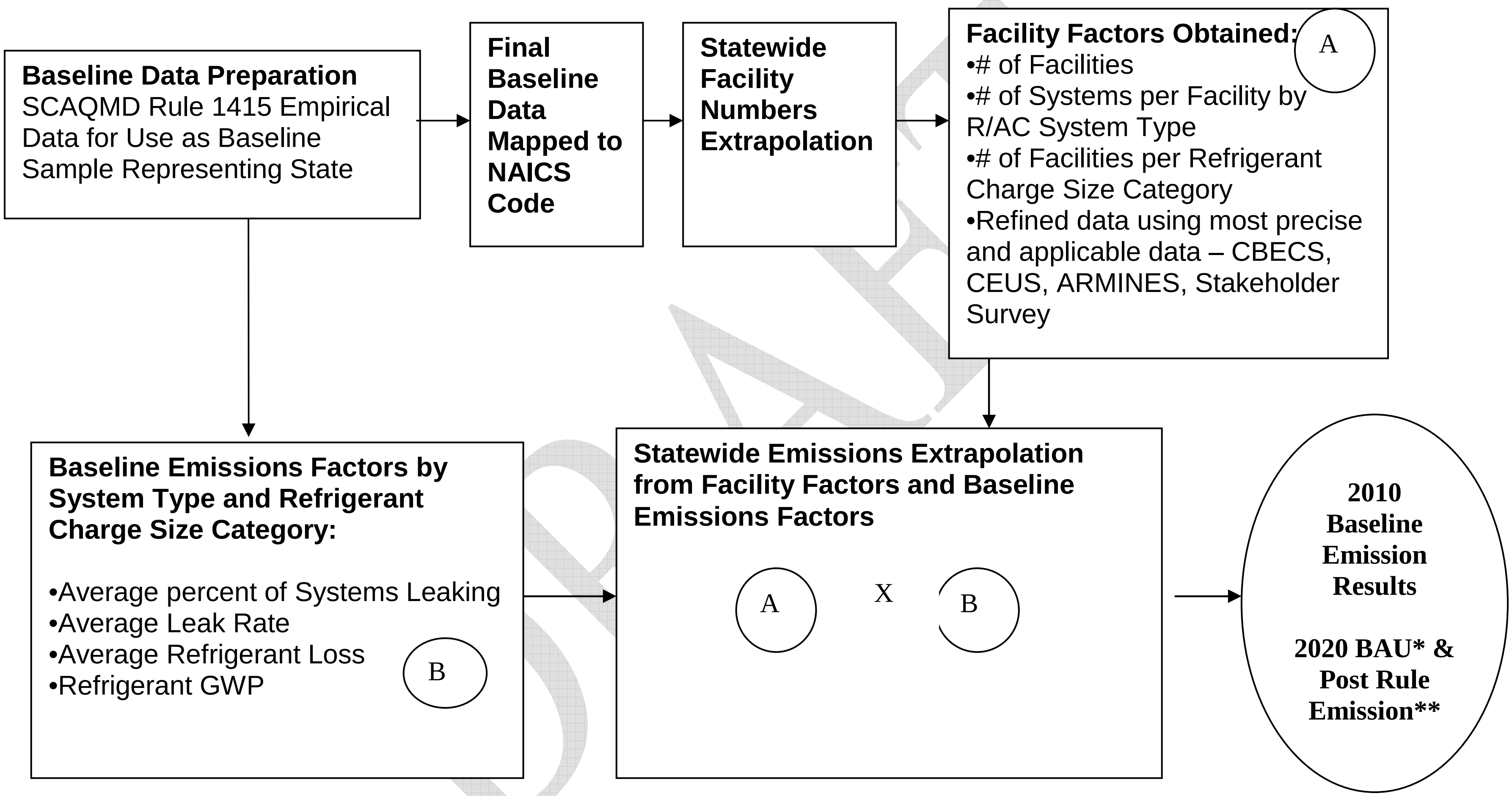
United Nations Environment Programme 2006 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, January 2007 (UNEP 2007): An update to the 1998 report, the updated report includes additional information on refrigerant leak rates under BAU scenarios and minimum achievable leak rates using best management practices for R/AC equipment. Used in conjunction with the IPCC Special Report to assign reasonable lower feasible and achievable leak rates for existing R/AC equipment.

B. Methods and Assumptions Used to Calculate Statewide Facility Number Estimates; Statewide R/AC System Number Estimates

The analyses to estimate statewide facility numbers and types, and R/AC system numbers and types were based upon empirical annual data available from biennial reports submitted in compliance with SCAQMD Rule 1415. The empirical data was refined by additional data sources when data was incomplete or more precise data was available. Results of using empirical data was cross-checked by comparing against additional data sources as described in methods sections B and C of this appendix.

The following Figure 1 flowchart summarizes the basic steps used to estimate emissions from stationary R/AC systems with refrigerant charges greater than 50 pounds. The methodology is more fully explained in following sections.

Figure 1. General Process Flowchart for Estimating GHG Emissions from Stationary Refrigerant Equipment



* Factors adjusted for growth or refrigerant transition for 2020 BAU calculation.
** Post Rule Leak Rate used for Post Rule Emissions.

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The SCAQMD Rule 1415 report data was used as the baseline of refrigerant usage patterns in California. The reports include the SIC code for each business completing a report. Reported SIC codes were mapped to NAICS codes and used, in conjunction with data provided by the US Census Bureau censtats database, to extrapolate the regional Rule 1415 data into a statewide estimate of the number of facilities in California in 2006. The data collected through Rule 1415 reporting were treated as a valid sample of state facilities, which were then extrapolated to statewide facility estimates for facility numbers and types of businesses potentially subject to the proposed rule. Adjustments were made for potential biases in the data set, including under-reporting (e.g., only equipment using ODS is regulated, facilities self-report) and imprecise facility categorization.

Facility descriptions for individual NAICS codes are generally too specific to be useful for broad characterizations of affected business types in California. As a result, individual NAICS codes mapped within this dataset were aggregated into broader facility type categories.

The Rule 1415 data used to determine affected facility types and numbers were further refined using building and energy use data from the Commercial Buildings Energy Consumption Survey (CBECS) administered by the Energy Information Administration.

Results were then further refined using additional facility and R/AC system data from the California Commercial End-Use Survey (CEUS) administered by the California Energy Commission. The CEUS data was used to correct for over-estimating numbers of facilities with R/AC equipment greater than 50 pounds, because the CEUS data contained information on the average cooling capacities of all business facilities (where Rule 1415 data contained only information on facilities with R/AC systems greater than 50 pounds). The CEUS data refined the numbers of R/AC system facilities slightly downward from Rule 1415 estimates extrapolated statewide. The combined results of these three sources of data and analysis yield the final facility and R/AC system number estimates.

The type of R/AC system was not always clear from the Rule 1415 reports. If the R/AC system description (for example, “cooling unit”) did not fit into a common description of a R/AC system type, a system was assigned based on the proportion of R/AC equipment type used in the same industry, with the same refrigerant and similar charge size. The U.S. EPA Vintaging Model technical assessments served as the basis to assign the most likely R/AC system type. An example of how this worked is in reporting of chiller equipment. There are two basic types of chillers: centrifugal and packaged. Most Rule 1415 reports did not specify which type of chiller was used. Therefore, Vintaging Model data was used to assign all chillers with charges greater than 2,000 pounds of refrigerant to the centrifugal chiller category, and 85 percent of chillers using less than 2,000 pounds of refrigerant to the packaged chiller category.

Detailed descriptions on exact methodology used to determine facility number and types; and number and types of R/AC systems are included at the end of this appendix in Addendum A in the following three sections:

1. Mapping of Reported SIC Codes to 2002 NAICS Codes
2. Estimates and Aggregation to Broad Facility Categories: Statewide Facility Number Estimates and R/AC System Number Estimates
3. Assumptions used to assign Equipment Type to Rule 1415 Data

C. Statewide Extrapolated CO_2E Emissions Estimates and Methodology

As described earlier, emissions estimates were based on the following equation:

Emissions ($MMTCO_2E$) =

*Number of facilities * systems/facility * average charge (lbs)/system * 4.54^{-10} lbs per MMT * GWP of refrigerant *average percent of systems leaking any given year * average percent of charge lost from leaking systems*

The following tables are summaries of emission estimates for three scenarios:

1) 2010 baseline emissions;
2) 2020 business as usual (BAU) emissions; and
3) 2020 emissions after implementation of the proposed regulation.

The emission reductions resulting from implementation of the proposed regulation is the difference between 2020 BAU and 2020 post-implementation.

The emission estimates were grouped into two different analysis sets. The first is by categorizing all equipment only by its refrigerant charge size (small, medium, and large). The second analysis consisted of categorizing equipment by both charge size and R/AC equipment type to allow for a more precise analysis of which types of systems tend to leak more frequently and contribute the most to emissions and which types of systems were less prone to leaks and therefore contribute less to emissions. For example, although the average annual leak rates for all large systems when looked at in entirety was 8%, additional analysis by R/AC equipment type revealed that actual leak rates for large systems range from less than 3% for large chillers to almost 30% for large cold storage systems.

The methodology used to calculate the emission and emission reduction estimates shown in the following tables is also described in this section.

Table 3. Summary of Emissions by R/AC Equipment Charge Size. All Emissions shown in $MMTCO_2E$ using the average value for number of facilities.				
	Emissions			**Emission Reductions**
Category	**2010 BAU**	**2020 BAU**	**2020 Post-Rule**	**2020 Total GHG Reduction**
Large Systems (≥ 2,000 lbs)	5.2	5.7	3.8	1.9 (1.5 HFC + 0.4 ODS)
Medium Systems (≥ 200 lbs, < 2,000 lbs)	16.7	18.5	8.7	9.8 (7.8 HFC + 2.0 ODS)
Small Systems (≥ 50 lbs, < 200 lbs)	5.9	6.5	2.8	3.9 (3.1 HFC + 0.8 ODS)
Totals	**27.8**	**30.7**	**15.3**	**15.5 (12.4 HFC + 3.1 ODS)**

In addition to the basic three refrigerant charge size categories of large, medium, and small, emission factors were also calculated based on ten distinct combinations, or categories of R/AC equipment type and refrigerant charge size categories. With three basic refrigerant charge size categories, and seven R/AC equipment types identified, theoretically, there could be 21 unique combinations of charge size and equipment type, but several combinations do not exist (such as large unitary AC systems, or small process cooling systems).

Table 4. Summary of Emissions by R/AC Equipment Type and Equipment Charge Size. All Emission shown in $MMTCO_2E$ using the average number of facilities.				
R/AC Equipment Type and Charge Category	**2010 BAU**	**2020 BAU**	**2020 Post-Rule**	**2020 Total GHG Reduction[3]**
Large Systems				
centralized refrigeration system	1.0	1.1	0.5	0.6 (0.5 HFC + 0.1 ODS)
centrifugal chiller large	1.2	1.4	1.4	0
cold storage large	1.8	2.0	0.7	1.3 (1.0 HFC + 0.3 ODS)
process cooling large	1.1	1.2	1.2	0
Medium Systems				
centralized refrigeration system medium	9.4	10.4	5.1	5.3 (4.3 ODS + 1.0 ODS)
centrifugal chiller medium	0.1	0.2	0.2	0
chiller packaged medium	5.6	6.2	3.2	3.0 (2.4 HFC + 0.6 ODS)
cold storage medium	1.6	1.8	0.4	1.4 (1.1 HFC + 0.3 ODS)

[3] In this analysis, estimated reductions for centrifugal chillers and process cooling are indicated as zero because emissions data from Rule 1415 reports indicate that these systems (as reported) already emit less than the expected lower achievable target leak rates defined for large systems that can be met through best management practices. However, when all emissions from all systems are aggregated, discrepancies between overall emissions from Rule 1415 data and from national Vintaging Model data are greatly decreased. Additional details are presented in Table 8.

R/AC Equipment Type and Charge Category	2010 BAU	2020 BAU	2020 Post-Rule	2020 Total GHG Reduction
Small Systems				
refrigerant condensing units small	1.6	1.7	0.6	1.1 (0.9 HFC + 0.2 ODS)
Unitary AC small	4.4	4.8	2.1	2.7 (2.2 HFC + 0.5 ODS)
Totals	**27.8**	**30.8**	**15.3**	**15.5 (12.4 HFC + 3.1 ODS)**

Emission Factors Methodology: After numbers of potentially affected facilities were estimated, it was necessary to determine the following emission factors in order to estimate GHG emissions (for both a BAU scenario, and under a rule post-implementation scenario):

- Numbers and types of R/AC systems per facility;
- Average charge size (pounds of refrigerant) per system;
- Types of refrigerants (and their global warming potentials) used in facility systems; including the ratio of R/AC systems that use HFC refrigerants compared to R/AC systems that use ODS refrigerants (and the comparative share of all HFC and ODS refrigerant use by both pounds and metric tons of CO_2 equivalents for both 2010 and projections for 2020);
- Average percent of systems leaking (during any given year);
- Average annual leak rate of leaking systems (pounds per year lost divided by the system charge) of those systems that are leaking;
- Amount of refrigerant leaked from leaking systems (in pounds and in $MMTCO_2E$); and
- Feasible lowest average leak rates from best management practice and maintenance, by each type of R/AC equipment and refrigerant charge size.

The following tables show emission factors and results of applying emission factors to estimate total emissions and emission reductions. Table 5 shows BAU in 2010, and Table 6 shows both BAU in 2020 and projected emission reductions expected as a result of the proposed regulation.

Additional details are given on how emission factors were developed following the summary tables.

Table. 5. Summary of Year 2010 Baseline Emission Factors

System Type	Bldgs	Systems	Systems/ Bldg.	charge (lbs) / system	% of systems leaking	% of charge leaked	Avg Annual Leak Rate	Total Annual. $MMTCO_2E$ Emissions for R/AC Type
centralized refrigeration system large	768	1,959	2.6	2,486	77%	28%	21%	1.0 (0.4 HFC + 0.6 ODS)
centralized refrigeration system medium	27,689	96,575	3.5	704	36%	43%	15%	9.4 (3.4 HFC + 6.0 ODS)
centrifugal chiller large	6,697	8,735	1.3	4,862	15%	16%	2.4%	1.2 (0.5 HFC + 0.7 ODS)
centrifugal chiller medium	5,708	13,919	2.4	1,007	6%	23%	1.4%	0.1 (0.03 HFC + 0.07 ODS)
chiller - packaged medium	30,564	142,675	4.7	526	18%	37%	6.8%	5.6 (2.1 HFC + 3.5 ODS)
cold storage large	1,488	1,488	1.0	7,546	77%	36%	27%	1.8 (0.8 HFC + 1.0 ODS)
cold storage medium	1,884	8,186	4.3	565	45%	80%	36%	1.6 (0.6 HFC + 1.0 ODS)
process cooling large	1,248	2,175	1.7	3,640	22%	31%	6.8%	1.1 (0.5 HFC + 0.6 ODS)
refrigerant condensing units small	29,399	106,041	3.6	122	22%	65%	14%	1.6 (0.6 HFC + 1.0 ODS)
unitary A/C small	120,088	528,453	4.4	100	19%	60%	11%	4.4 (1.7 HFC + 2.7 ODS)
HFC Only Total Emissions								**10.6**
ODS Only Total Emissions								**17.2**
Total GHG Emissions								**27.8**

Table 6. Summary of Year 2020 Emission Factors, BAU Emissions and Emission Reductions

System Type	Bldgs	Systems	Systems/ Bldg.	charge (lbs) / system	% of systems leaking	% of charge leaked	Avg Annual Leak Rate	Total Annual. $MMTCO_2E$ Emissions for R/AC Type	Feasible Lower Avg. Annual Leak Rate[1]	New Total Ave. $MMTCO_2E$ Emissions:	Emission Reductions/ year:
centralized refrigeration system large	848	2,164	2.6	2,486	77%	28%	21%	1.1	10%	0.5	0.6 (0.5 HFC + 0.1 ODS)
centralized refrigeration system medium	30,586	106,678	3.5	704	36%	43%	15%	10.4	7.5%	5.1	5.3 (4.3 HFC + 1.0 ODS)
centrifugal chiller large	7,397	9,648	1.3	4,862	15%	16%	2.4%	1.4	2.4%	1.4	0.0
centrifugal chiller medium	6,305	15,375	2.4	1,007	6%	23%	1.4%	0.2	1.4%	0.2	0.0
chiller - packaged medium	33,761	157,600	4.7	526	18%	37%	7%	6.2	3.5%	3.2	3.0 (2.4 HFC + 0.6 ODS)
cold storage large	1,644	1,644	1.0	7,546	77%	36%	27%	2.0	10%	0.7	1.3 (1.0 HFC + 0.3 ODS)
cold storage medium	2,081	9,042	4.3	565	45%	80%	36%	1.8	7.5%	0.4	1.4 (1.1 HFC + 0.3 ODS)
process cooling large	1,379	2,402	1.7	3,640	22%	31%	6.8%	1.2	6.8%	1.2	0.0
refrigerant condensing units small	32,475	117,136	3.6	122	22%	65%	14%	1.7	5%	0.6	1.1 (0.9 HFC + 0.2 ODS)
unitary A/C small	132,653	583,746	4.4	100	19%	60%	11%	4.8	5%	2.1	2.7 (2.2 HFC + 0.5 ODS)
HFC Only Total Emissions								**24.6**		**12.2**	**12.4**
ODS Only Total Emissions								**6.2**		**3.1**	**3.1**
Total GHG Emissions								**30.8**		**15.3**	**15.5**

[1] The feasible lower annual leak rate is a weighted average that applies to the entire system category rather than only those systems that are leaking.

Discussion on methodology used to establish specific emission factors:

1. Numbers and types of refrigerant or air conditioning systems per facility:

As indicated in the previous section on facility number estimates, SCAQMD Rule 1415 empirical data was used as the basis to extrapolate numbers and types of R/AC systems per facility to statewide averages. For each reporting facility, the numbers and types of R/AC systems (by equipment type and by charge size) were summed for each category; and divided by the number of facilities containing the equipment category.

The following equation was used for each of the ten distinct R/AC equipment groups:

Average number of pieces of R/AC equipment per facility =
Number of R/AC Systems/Number of facilities containing that type of system

R/AC systems per facility were also independently calculated using CEUS survey data using the same method. CEUS data showed about 20 percent fewer systems per facility than the Rule 1415 data. Results between CEUS data and Rule 1415 were averaged to arrive at an average number of R/AC systems per facility.

2 Average charge size (pounds of refrigerant) per system:

Similar to the methodology used to determine the average number of R/AC systems per facility, Rule 1415 data indicated charge sizes for each piece of equipment were summed and divided by the total pieces of that equipment type:

Average charge size per system =
Total pounds charge (by R/AC system group)/total systems (by R/AC system group)

CEUS data was used to independently calculate average charge size. The CEUS data level of precision for this factor is lower than the Rule 1415 average, because an additional conversion was necessary for CEUS data. Specifically, the CEUS data did not report the actual charge size of systems in pounds, but was reported in terms of tons of cooling capacity for the system, which had to be converted to an equivalent charge size in pounds. The conversion factors used were that every ton of cooling capacity for AC systems was equivalent to 3.5 pounds of refrigerant, and every ton of cooling capacity for refrigeration systems was equivalent to 5 pounds of refrigerant. CEUS data was within ten percent of Rule 1415 data, but only Rule 1415 data was used because it was more precise. As an additional cross-check, average charge sizes were compared to Vintaging

Model technical assessments, which indicated a wide range of average charge sizes. Rule 1415 data fell well within Vintaging Model charge size parameters.

3. Types of refrigerants (and their global warming potentials) used in facility systems:

Rule 1415 data was used to establish a preliminary baseline for 2010 because all reports indicated the type of refrigerant used. However, an inherent bias was recognized within Rule 1415 immediately – only ODS-containing systems were required to report; therefore, HFC-containing systems would be significantly absent. Because Rule 1415 only requires ODS refrigerant reporting, use of this data set without adjustment will likely under-estimate statewide emissions of HFCs.

The Rule 1415 data was refined by using Vintaging Model estimates on the actual distribution of units of specific types of equipment using either ODS or HFC in use today. Projections of refrigerant use in 2020 by the Vintaging Model were also provided to the ARB by the U.S. EPA. For a given type of R/AC equipment, the Vintaging Model refrigerant distribution (units distribution) was assigned to normalize Rule 1415 refrigerant data to actual refrigerant usage. For example, if 100% of the large chillers reported in Rule 1415 that an ODS refrigerant was used, but Vintaging Model data indicated that nationally, 20% of large chillers use HFC refrigerants, then 20% of the large chillers in Rule 1415 were randomly chosen and assigned HFC refrigerant to reflect the national distribution. Random assignment was used to prevent any systematic bias against associating high-leakage systems with any particular type of refrigerant.

Note that in about five percent of the Rule 1415 reports, the refrigerant reported was indecipherable or inconclusive, such as “refrigerant R”, or “Freon”. Where the refrigerant used could not be ascertained, it was immediately selected for random assignment of normal refrigerant distribution for that type of system. Where the refrigerant used was inconclusive, such as “Freon”, the normal distribution of Freon-type refrigerants were assigned according to R/AC system.

The U.S. EPA Vintaging Model projects that the proportion of R/AC equipment utilizing ODS refrigerants will decline from 2010 to 2020 and use of HFC refrigerants will increase as ODS refrigerants are phased out. Table 7 illustrates the ODS and HFC ratios that were used to assign realistic baseline (2010) refrigerant usage, and projected 2020 refrigerant usage. These projections are based on the number of R/AC systems currently in place, ODS phase-out schedules and their most probable non-ODS refrigerant replacements, and the average lifetime of equipment. Aggregated industry data is used to estimate current R/AC systems and their lifetimes. Projecting the likely non-ODS refrigerant replacements is based upon current usage trends, assuming that refrigerant transitions occur linearly from the start date until the date of full usage.

The U.S. EPA's Vintaging Model often uses several sets of transitions to better approximate non-linear transitions, such as the transition of AC equipment from HCFC-22 to HFC blends. The following table showing projected refrigerant distribution in 2010 and 2020 is derived from projections made in 2003, and is expected to be revised and updated in 2009.

Table 7. U.S. EPA Vintaging Model distribution trends of refrigerant use by equipment type in 2010, and projected distribution in 2020 (percent of GWP weighted refrigerant use.).

Equipment type	Refrigerant	GWP	% Equipment 2010	% Equipment 2020	HFC or ODS
unitary A/C	HCFC 22	1500	50%	12%	ODS
	R 410a	1730	50%	88%	HFC
chillers	HCFC 22	1500	9%	6%	ODS
	CFC 11	3800	13%	0%	ODS
	CFC 12	8100	1%	0%	ODS
	HCFC 123	90	37%	42%	ODS
	HFC 134a	1300	38%	51%	HFC
	HFC 236fa	6300	1%	1%	HFC
	R 500	6010	1%	0%	ODS
refrigerant condensing units	CFC 12	8100	10%	0%	ODS
	HCFC 22	1500	20%	8%	ODS
	HFC 134a	1300	40%	43%	HFC
	R 404a	3260	20%	31%	HFC
	R 507	3300	10%	18%	HFC
centralized systems	HCFC 22	1500	40%	6%	ODS
	R 404a	3260	42%	65%	HFC
	R 502	5490	0%	0%	ODS
	R 507	3300	18%	29%	HFC
cold storage	CFC 12	8100	3%	0%	ODS
	HCFC 22	1500	55%	26%	ODS
	R 502	5490	7%	0%	ODS
	HFC 134a	1300	7%	7%	HFC
	R 404a	3260	19%	47%	HFC
	R 507	3300	9%	20%	HFC
process cooling	HCFC 22	1500	22%	12%	ODS
	CFC 11	3800	1%	0%	ODS
	CFC 12	8100	18%	0%	ODS
	HCFC 123	90	24%	23%	ODS
	R 410a	1730	1%	2%	HFC
	R 404a	3260	2%	11%	HFC
	HFC 134a	1300	32%	49%	HFC
	R 507	3300	0%	3%	HFC

No break-out by charge size was available, but assessment of the U.S. EPA Vintaging Model data indicates that types of refrigerants used by R/AC equipment type are generally consistent across all charge sizes for a given equipment type. Similarly, chiller refrigerant use was assigned the same for both centrifugal and package chillers.

Global warming potentials (GWPs) were assigned according to the values for the 100-year time horizon as reported in the IPCC Second Annual Report (SAR). For some refrigerant GWP values not shown in the SAR, the IPCC Third Annual Report (TAR) values were used.

4. Average percent of systems leaking (during a given year):

Rule 1415 data was the best source of data for this factor, as other data tended to report annual leak rates assuming that all equipment leaked a certain amount each year.

The factor is calculated from:

Number of systems reporting a leak/total number of systems.

5. Average leak rate of refrigerant leaked from leaking systems:

Rule 1415 data was used in the following equation:

Annual leak rate for a leaking system =
*Pounds refrigerant lost (added) to equipment annually/total charge (lbs) of leaking equipment * 100%*

All refrigerant losses were summed for each specific R/AC category and divided by the summed total of all refrigerant charge within the R/AC category. Average leak rates were also computed for individual systems, which agreed well with the overall weighted average loss for all leaking systems. However, the weighted averages for refrigerant losses from all leaking systems results in a more precise estimate than taking an average of all the average individual losses.

Given the percent of systems leaking in a given year, and the average leak rate of refrigerant leaked from leaking systems, the average annual leak rate for all systems could be calculated:

Average annual leak rate =
*Percent systems leaking * average leak rate (pounds lost/total pounds of charge) of leaking systems.*

Emission projections under a BAU scenario for 2020 assumes that current leak rates of equipment remain constant through 2020; although more leak-tight systems may be developed in the future.

6. Average amount of refrigerant leaked from leaking systems (in pounds and in $MMTCO_2E$):

Amount of refrigerant leaked from all leaking systems =
*Average percent of leaking systems * the average leak rate of those leaking systems * total pounds of charge of all systems within the R/AC category.*

To convert output from pounds to MMTCO2E:

Leak size in $MMTCO_2E$ =
*Leak pounds * conversion factor of 4.54^{-10} lbs per MMT * GWP of refrigerant.*

7. Feasible lowest average leak rates by equipment type and charge size:

It is not possible to prevent all refrigerant leaks in R/AC systems. Normal aging of equipment, weakened fittings and gaskets, and normal wear and tear that lead to leaks are part of R/AC equipment usage in the real world. However, it is possible to find and repair leaks more quickly when best practice in refrigerant management and system maintenance is utilized. One major assumption used to estimate emission reductions is that the proposed rule would not necessarily reduce the actual number, or percent of leaking R/AC systems during any given year. Rather, the rule defines inspection and maintenance best management practices and use of these practices would cause leaks to be detected and repaired more quickly and completely than without the rule in place, reducing overall refrigerant emissions.

In order to calculate emission reductions from BAU to post-rule implementation, it was necessary to first estimate by how much the annual leak rate could be reduced, then to quantify those emissions.

Two key sources were used as the basis of lower achievable leak rates: The United Nations Environment Programme (UNEP) *2006 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee*, and the Intergovernmental Panel on Climate Change [IPCC] and Technology and Economic Assessment Panel [TEAP] *Special Report on Safeguarding the Ozone Layer and the Global Climate Systems, 2005*. U.S. EPA Vintaging Model technical sheets on specific R/AC equipment types normal leak rates were also used as references.

The references indicate that using best management practices on equipment (old or new equipment) can reduce the average annual leak rates to 10 percent or less for large equipment (2,000 pound charge or greater), and five percent or less for small equipment with less than 200 pounds. To assign an achievable leak rate to medium equipment (200 pounds to 2,000 pounds), a midpoint of 7.5 percent achievable leak rate was used.

The data sources also contained information on specific R/AC equipment sizes, which was more precise in assigning achievable lower leak rates. For example, chillers were identified as the R/AC equipment type that is the exception to the generalized achievable leak rates based on charge size. The U.S. EPA Vintaging Model estimates that ODS-containing, very large chillers (2,000 pounds of charge or greater) have average leak rates (currently) of only 9% per year, medium-sized centrifugal chillers have leak rates of 7% per year, and medium-sized package chillers have leak rates of only 3.5% per year. In the U.S. EPA Vintaging Model, these loss rates are much lower for the newer, ODS substitute equipment types.

The following table shows average annual leak rates for all equipment as shown in the Rule 1415 data on actual usage (refrigerant losses) for a variety of R/AC equipment types over six consecutive years. Note that in some cases, the current average leak rate for all equipment in the Rule 1415 data set is roughly equivalent or lower than the achievable lower leak rates indicated by the UNEP research.

Table 8. R/AC Equipment Leak Rates, BAU compared to Post-Implementation of Rule. R/AC equipment annual leak rates are based on data reported under SCAQMD Rule 1415 usage reports. Lower achievable average annual leak rates using best management practices are based on industry studies reported in the IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate Systems (IPCC/TEAP 2005); and the UNEP Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, October 1998, Annex III Refrigerant Data (UNEP 1998).

Table 8. R/AC Equipment Leak Rates, BAU compared to Post-Implementation of Rule

R/AC Equipment Type and Charge Category	Rule 1415 Data - Avg. Annual Leak Rate	Lower Achievable Avg. Annual Leak Rate w/ Best Mgmt. Practices	Reduction of Leak Emissions (relative %)
centralized system (large)	21.5%	10%	53%
centralized system (medium)	15.4%	7.5%	51%
centrifugal chiller (large) [4]	2.4%	2.4%	0%
centrifugal chiller (medium)	1.4%	1.4%	0%
chiller packaged (medium)	6.8%	3.5%	49%
cold storage (large)	27.5%	10%	64%

[4] Detailed note on chiller leak rates: Chillers can be designed and maintained to have very low leak rates, with average annual leak rates between 2% to 16.5%, with a lower leak rate of 2-4% annually thought to be achievable using best management practices. The Rule 1415 dataset did not separate types of chillers into centrifugal or packaged chillers. All chillers were grouped together. ARB staff reviewed available data and made the following assumptions: All chillers with a charge size 2,000 pounds or greater were centrifugal chillers. Packaged chillers comprise 85% of all chillers with charges less than 2,000 pounds. Eighty-five percent of the Rule 1415 chiller equipment (less than 2,000 pounds) were randomly assigned as packaged chillers, and the remaining 15% were assigned as centrifugal chillers. When all Rule 1415 chiller data is aggregated into one chiller category, the average annual leak rate is 4.2%. The "target" leak rates of 2.4% and 1.4% for centrifugal chillers (large and medium-sized, respectively), remains as a target because chillers collectively as shown within the dataset are already able to achieve a low annual leak rate.

Table 8. R/AC Equipment Leak Rates, BAU compared to Post-Implementation of Rule			
R/AC Equipment Type and Charge Category	**Rule 1415 Data - Avg. Annual Leak Rate**	**Lower Achievable Avg. Annual Leak Rate w/ Best Mgmt. Practices**	**Reduction of Leak Emissions (relative %)**
cold storage (medium)	36.2%	7.5%	79%
process cooling (large)[5]	6.8%	6.8%	0%
refrigerant condensing units (small)	14.5%	5%	65%
Unitary AC (small)	11.3%	5%	56%
Overall Total all systems, all leaks	**10.4%**	**5.2%**	**50%**

To help inform discussion of the current status of existing facilities and their ability to achieve "target" lower achievable average annual leak rates for their R/AC systems, the following table using refrigerant loss data from Rule 1415 reports is shown. For each R/AC group, the average annual percentage of systems (reporting years 1999-2005) that have emitted less than the target leak rate is shown. For example, in the row for centralized system (large), the 44% indicates that on average, in any given reporting year, 44% of the systems are able to meet target leak rates because they emit less than ten percent of their refrigerant charge. A value of 100% would indicate that all systems are achieving emission rates that are lower than the target rates.

Table 9. Percent of R/AC Systems Currently Achieving Target Leak Rates		
R/AC Equipment Type and Charge Category	**Lower Achievable (Target) Leak Rate**	**Annual Percent of Systems emitting less than "target" leak rate**
centralized system (large)	10%	44%
centralized system (medium)	7.5%	66%
centrifugal chiller (large)	2.4%	85%
centrifugal chiller (medium)	1.4%	94%
chiller packaged (medium)	3.5%	82%
cold storage (large)	10%	37%
cold storage (medium)	7.5%	56%
process cooling (large)	6.8%	81%
refrigerant condensing units (small)	5%	78%
Unitary AC (small)	5%	82%

5 Detailed note on Process Cooling Leak Rates: Data from the U.S. EPA Vintaging Model, IPCC Third Annual Report, and ARMINES indicate that large process cooling units tend to leak 10% of their refrigerant each year. It is not known why the process cooling systems under Rule 1415 have lower leak rates than other estimates. ARB analysis assumes that the rule will not increase process cooling refrigerant emissions in California, but there is little justification in arbitrarily assigning a lower leak rate than the one that currently exists, as other information indicates any leak rate less than 10 percent is already in compliance with best management practices.

8. Potential Biases and Uncertainties in Data

Potential biases inherent in the Rule 1415 baseline dataset and resulting statewide extrapolations included:

1) Very little HFC refrigerant usage and loss data was available, as the Rule only applies to R/AC systems containing ODS refrigerants (although about three percent of facilities did report HFC refrigerant usage).

2) Over-estimation of the percent of facilities (within a given NAICS code) containing R/AC systems with refrigerant charges greater than 50 pounds, as no facilities with refrigerant charges less than 50 pounds are required to report.

3) Under-reporting resulting from facilities that do not report, but are required to report by regulation. Although no exact numbers are available to quantify the number of facilities that fail to report, reasonable estimates from extrapolation of facility types within the SCAQMD region suggest that less than twenty percent of regulated facilities submit required reports. Bias could be introduced in two ways: 1) lower leak rates than representative of the general R/AC system population because the facilities that report tend to be the ones that already have best management practices (and therefore low leak rates); or 2) higher leak rates than representative, because facilities that report do so because they have been identified by local environmental enforcement agencies for serious or minor violations of environmental regulations, and have been told to report for Rule 1415 and other environmental regulations. ARB staff believes it is likely that both scenarios exist, nullifying the positive and negative biases and rendering them neutral, leaving a valid non-biased sample from under-reporting of facilities.

Uncertainties in Rule 1415 data and resulting statewide extrapolations:
In addition to the potential biases discussed above, two uncertainties were identified that could result in higher and lower baseline emission estimates:

1) As noted in Table 1 that shows the estimated number of facilities, a reasonable range of potentially affected facilities exists. Depending on using either the upper or lower range of the number of facilities used in calculations of emissions, the range of calculated emissions is plus or minus 15 percent from BAU average estimated emissions for 2010 and 2020. Additional details on the methodology to estimate facility numbers and uncertainties are provided in Addendum A of this appendix.

2) Leak rates of R/AC equipment were analyzed to determine how closely reported data matched national and international estimates. The leak rates of R/AC equipment reported under Rule 1415 were compared to national estimated leak rates of R/AC equipment, using three data sources for national estimates: U.S. EPA Vintaging Model, ARMINES analysis, and IPCC reports. Based on the range of lower to upper annual leak rates from these data sources, the range of calculated emissions from the average is plus or minus 35 percent from BAU estimated emissions for 2010 and 2020.

Due to these potential biases and uncertainties, the empirical data required additional refining from several other data sources as previously described in this appendix. The additional data sources were also used to cross-check estimates and assumptions from the primary source of data (Rule 1415 reports).

4. Summary and Conclusions

Summary:

Statewide estimates of the number of facilities using R/AC equipment with greater than 50 pounds of refrigerant were calculated and refined using several data sources. Facility number estimates were refined using additional data sources whenever possible to reduce known sources of bias for specific facility types. Refined facility number estimates revealed that the majority of impacted facilities in California, approximately 65% of the total, use R/AC equipment with refrigerant charges between 50 – 200 lbs. Approximately 30% use R/AC equipment with refrigerant charges between 200 – 2,000 lbs, and only a very small proportion, approximately 5%, use R/AC equipment with refrigerant charges greater than 2,000 lbs.

Statewide facility number estimates were used to calculate the emissions inventory for stationary commercial and industrial R/AC equipment in California. Emissions inventory estimates were calculated using R/AC equipment use patterns and annual leak rate data provided in the rule 1415 dataset. Estimates of the distribution of R/AC equipment using specific HFC and ODS refrigerants were obtained from the U.S. EPA Vintaging Model estimates and applied to the rule 1415 dataset. Refrigerant use distributions were adjusted to reduce a known bias in the rule 1415 data set generated by a requirement to report refrigerant use patterns for only refrigeration systems utilizing ODS refrigerants.

Finally, the reductions in emissions that could be associated with implementation of the proposed regulation and full compliance were estimated. Assuming reduced leak rates, as a result of improved maintenance practices and regular monitoring for all R/AC equipment in California, resulted in estimated CO_2E emission reductions of about 50 percent.

Conclusions

The Refrigerant Management Program proposed regulation is anticipated to result in significant GHG emission reductions. The primary emission reductions are a result of the leak detection and monitoring and leak repair components of the proposed rule. The reporting and record-keeping components ensure that the emission reductions are real, verifiable, and enforceable.

HFC emissions inventory estimates for the total annual CO_2 equivalent emissions from leaks associated with stationary commercial and industrial R/AC equipment in California in 2010 are about 11 $MMTCO_2E$, and projected to increase to almost 25 $MMTCO_2E$ by 2020 under the BAU scenario.

Analyses conducted by ARB staff estimate that 50% of the CO_2E emissions from stationary R/AC equipment could be eliminated relative to BAU as a result of implementing inspection and maintenance best practices such as the detection and monitoring and leak repair practices required by the proposed rule. Annual emission reductions are expected of about 12.4 $MMTCO_2E$ HFCs and another 3.1. $MMTCO_2E$ ODS (15.5 $MMTCO_2E$ total) from BAU by the year 2020.

Addendum A – Additional Methodology Details

Section 1. Mapping of Reported SIC Codes to 2002 NAICS Codes

Methods: All data obtained from SCAQMD databases were initially scanned for errors and reasonable attempts to fill the data gaps were made, whenever possible. For example, facilities occasionally did not report an SIC code but did include specific business descriptions which were identical to descriptions provided by other facilities reporting an SIC code. In these cases the facilities with missing SIC codes were assigned the same SIC codes as facilities with identical business descriptions. Additionally, if a facility provided a business description that was sufficiently specific, a three digit SIC code was assigned to the respective facility based on NAICS code business descriptions. If a facility did not report an SIC code and the description provided was too vague to allow confident assignment of a three digit SIC code the data was not incorporated in further analyses.

The US Census Bureau NAICS code website was used to obtain a better understanding of the types of facilities included within each NAICS or SIC code throughout this process. In many cases the reported SIC code was mapped to a NAICS code based on the suggested mapping scheme provided by the US Census Bureau. In cases where two-digit SIC codes were reported, direct mapping to a NAICS code was not possible. In these cases the specific business description reported by each facility and the reported SIC code were used as guides to map a three- to four-digit NAICS code. In general, the business description was relied upon more heavily than the reported SIC code because it was assumed that the employee reporting to the SCAQMD was better able to accurately describe their business than assign an appropriate SIC code from the list provided. Additionally, if SIC codes or business descriptions reported were vague, mapping to fewer NAICS digits was used to avoid over-specifying facility categories.

Assumptions/sources of bias: Several assumptions are implicit in the methods used to map SIC codes/business descriptions to NAICS codes described. It is necessary to assume that the employees completing and submitting the reporting forms to the SCAQMD accurately selected SIC codes to represent their primary business activity and that the business descriptions provided are also accurate. It is possible that the employee reporting included a business description that they felt reflected the goals of the SCAQMD instead of the actual business conducted there (for example: including a business description for a real estate office building that contains a chiller as “building cooling” instead of “real estate”). It is also necessary to assume that, during the SIC to NAICS code mapping process, accurate assessments of facility types included within each NAICS or SIC code were made based on information obtained from the US Census Bureau NAICS code website.

Finally, it is necessary to assume that data within the SCAQMD Rule 1415 dataset is accurate. Data was initially obtained as hard copies and converted to an electronic format using optical character recognition software. It is possible that errors were made during the process of converting data from hard copies to electronic format. However, any errors made during data transcription would have been compensated for by cross-checking the data for reasonableness and how well it reflected actual R/AC numbers and refrigerant usage patterns, as compared to data from CBECS survey, CEUS survey, Armines research, and the U.S. EPA Vintaging Model.

Section 2. Estimates and Aggregation to Broad Facility Categories
Statewide Facility Number Estimates and R/AC System Number Estimates

After NAICS code mapping was conducted and all NAICS codes were assigned, the numbers of facilities were determined. Facilities were designated further into categories by type of R/AC equipment and refrigerant charge size category.

System Size Ranges: Datasets for each of the three R/AC system ranges were generated by sorting SCAQMD data by equipment charge size into the three main charge sizes (small, medium, and large). The data was also sorted according to type of R/AC equipment used within a given charge size. For example, the small equipment category consists of equipment that is either a refrigerated condensing unit or a unitary AC system.

Statewide Extrapolation: The next step to calculate numbers of facilities potentially impacted by the proposed regulation was to determine the number of facilities statewide in each of the NAICS codes represented in the Rule 1415 dataset. All of the mapped NAICS codes from the Rule 1415 data represented in each of these datasets (small, medium, and large R/AC systems) were identified. Statewide facility number estimates for each NAICS code represented in each refrigerant charge size range were obtained from the US Census Bureau censtats database. The sum of these statewide facility number estimates provided the preliminary statewide estimates for facilities using R/AC equipment within each R/AC system size range. As a result, the statewide facility number estimate for a given NAICS code was included for a given size range if it had at least one facility with at least one piece of equipment with a reported refrigerant charge size above that category threshold.

One assumption used in this approach was that SCAQMD Rule 1415 data was a valid sampling of statewide data. This is a reasonable assumption because it most likely over-estimates R/AC systems used in cooler parts of the state (such as the Bay Area), but underestimates R/AC systems used in warmer parts of the state (Central Valley, desert regions).

To simplify data presentation, individual NAICS codes were assigned to aggregated categories representing broad facility types in California. After statewide facility number estimates for all represented NAICS codes were determined within each R/AC system size category, the estimates were summed to yield a cumulative facility number within each aggregated category.

The following table shows the NAICS codes that were assigned to aggregated categories of business types. Many aggregated categories consist of multiple NAICS codes because the codes are for very specific types of businesses, where the aggregated categories represent very broad business types, such as office buildings.

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Table 10. List of mapped NAICS codes included within each aggregated facility category.

Aggregated category	Mapped NAICS codes				
Agricultural service	115000				
Airport	488110				
Amusement/recreation parks	713990	713950	713110	711211	711110
	711219				
Beer and ale	424810	312120			
Bottled gas dealers	454312				
Cemeteries/crematories	812220				
Dairy	311513	311511	311510		
Department stores	452111				
Education - Junior colleges	611210				
Education - tech and trade schools	611519				
Education - universities	611300				
Elementary and secondary schools	611110				
Food processing	311812	311111	311000		
Fresh fruit and vegetable wholesale	493110	424490	424420	424410	
Frozen food wholesale	424480				
Fruit and vegetable processing	311421	311400			
Hotels/motels	721110				
Ice manufacturing	312113				
Libraries	519120				
Manufacturing (non-food)	346000	339992	339930	334613	334220
	339910	339115	339110	334516	333315
	339100	339000	336419	334511	332813
	336414	336411	336410	336400	332811
	336322	336300	335911	335313	333319
	331512	331316	331111	331000	327310
	327213	326192	326160	326140	326113
	325991	325910	325620	325610	325520
	325510	325414	325412	325411	325320
	325300	325211	325120	325000	323110
	322210	322200	322120	313000	

Table 10. List of mapped NAICS codes included within each aggregated facility category.

Aggregated category	Mapped NAICS codes				
Meat processing	311710	311612	311611	311600	332722
Medical care	623110	622310	622110	621512	332431
Misc warehousing/storage	493190				
Museums	712130	712110			
Office buildings	813990	813930	813910	621100	561439
	551112	551100	541860	541511	541330
	541110	541000	531312	531110	524298
	522390	522110	518210	518111	425000
	238910	236000			
Petroleum	324110	324000	221110		
Pharmacies	446110				
Publishing	511130	511120	511110	423910	323117
Refrigerated warehousing/storage	493120				
Religious organizations	813110	813000			
Research and development	541710				
Retail (food)	445299	445200	445110	445000	
Retail (non-food)	454390	453998	452000	448310	442110
	441110				
Semiconductor	334414	334413	334410		
Service industry	811490	811198	561720		
Telecommunications	517110				
TV/movie production	515120	512191	512110		
Utilities	221320	221310	221210	221119	221000
	211111	56221			
Wholesale - (non-food)	424690	424100	423410	423110	422110

Adjustments for Potential Bias

<u>Distribution of System Sizes</u>

Because there is likely to be a distribution of equipment sizes within a given facility category, statewide facility estimates for the medium and large system size ranges were adjusted (using the following equations 1a and 1b) based on the ratio of the number of SCAQMD facilities reporting within each aggregated facility category (e.g., department stores) to the number of SCAQMD facilities included within that size range only.

Equation 1a:

$$\textit{200 lb threshold adjusted facility number estimate} = (\textit{\# reporting facilities}_{\textit{Rule 1415>200lb}} / \textit{\# reporting facilities}_{\textit{Rule 1415 >50lb}}) * \textit{\# facilities}_{\textit{statewide}}$$

Equation 1b:

$$\textit{2,000 lb threshold adjusted facility number estimate} = (\textit{\# reporting facilities}_{\textit{Rule 1415>2,000lb}} / \textit{\# reporting facilities}_{\textit{Rule 1415>50lb}}) * \textit{\# facilities}_{\textit{statewide}}$$

The number of facilities with 50-200 pound systems is estimated by subtracting the medium and large category estimates from the total number of facilities with a facility category.

<u>Imprecise Facility Categories</u>
Additional steps were taken to reduce potential errors in extrapolating from SCAQMD data. The process of mapping to NAICS codes and aggregating to broader facility categories revealed several problematic facility types that were difficult to accurately map to NAICS codes. Challenging NAICS codes typically included many facilities which reported only vague business descriptions (such as “office” or “retail food”) and only two digit SIC codes. The lack of specificity in the reports meant that mapping to only very broad NAICS (3 digit) categories was possible.

Facility categories with imprecise codes include: retail food, pharmacies, hotels/motels, cold storage/food processing (including agricultural service, beer and ale, dairy, food processing, fresh fruit and vegetable wholesale, fruit and vegetable processing, meat processing, and refrigerated warehousing or storage), and office buildings. For these facility categories, estimates obtained from independent data sources, as described in the subsequent summaries, were used to replace estimates obtained from analysis of Rule 1415 data.

Retail food: ARMINES (2008) conducted site visits and surveys of retail food establishments and other facility categories in California as part of contract 06-325 with ARB, “Inventory of Direct and Indirect GHG Emissions from Stationary Air Conditioning and Refrigeration Sources, with Special Emphasis on Retail Food Refrigeration and Unitary Air Conditioning”. The results are presented in the July 2008 Provisional Report (same title as the contract).

The survey provides an accurate estimate of the total number of retail food establishments in California that use R/AC equipment with refrigerant charge sizes greater than 50 lbs (including grocery stores, minimarkets, and convenience stores; 10,380 facilities total). The ARMINES data on the number of retail food establishment (grocery stores, supermarkets, restaurants) was more precise than extrapolated estimates from Rule 1415 data, and therefore the ARMINES data was used in place of Rule 1415 estimates for the retail food category.

The ARMINES report provided enough information on R/AC equipment and charge sizes used by the retail food industry to break out the number of retail food facilities into facilities with refrigerant charges that are large, medium, or small.

Pharmacies: Survey data provided in ARMINES (2008) on pharmacies was used to estimate the number of pharmacies in California for the small and medium R/AC system thresholds.

Hotels/Motels: Facility number estimates for the hotel/motel category were taken from survey data on hotels from ARMINES (2008). This report indicated that motels use small window AC units, and do not use R/AC equipment with refrigerant charges above 50 lbs. As a result, motels would not be affected by the proposed rule. Additionally, the facility number estimate for hotels using R/AC equipment with more than 2,000 lbs of refrigerant was reduced by 85% based on the assumption that R/AC equipment used by hotels at this refrigerant charge size threshold were limited to chillers. The distribution of chiller charge sizes within the Rule 1415 dataset indicates that only approximately 6% of chillers in use in California have refrigerant charges greater than 2,000 lbs. This assumption was verified by an analysis of the U.S. EPA's Vintaging Model R/AC system distribution data as well.

Cold storage/food processing: ARB staff contacted stakeholders including equipment manufacturers, produce and vegetable growers, and other industry stakeholders to verify ARMINES research indicating that at least 80% of cold storage and food processing facilities in California use ammonia or CO_2 as their refrigerant, and thus would not be subject to the proposed rule. Stakeholders were able to verify this assumption, and based on this information, facility number estimates at all refrigerant charge sizes for cold storage and food processing categories (including agricultural service, beer and ale, dairy, food processing, fresh fruit and vegetable wholesale, fruit and vegetable processing, meat processing, and refrigerated warehousing/storage) were reduced by 80%.

Office buildings: The office building estimates were adjusted using data obtained from the nationwide CBECS report, scaled down to California, and the CEUS survey (described in greater detail at the end of this addendum section). The CBECS report provided characterizations of commercial heating, ventilation, and air-conditioning (HVAC) equipment use for broad facility categories, including office buildings and office complexes. Using this dataset, the number of offices in California using HVAC equipment with refrigerant charges greater than 50 lbs, 200 lbs, and 2,000 lbs were cross-checked against the Rule 1415 dataset and its facility extrapolations.

Estimates on the number of office buildings by charge size category was obtained by scaling the nationwide number of buildings utilizing HVAC units of different sizes to California's proportion of national estimates, based on population size (California is 12.8% of the national population).

Facility number estimates for California were obtained for each NAICS code using the US Census Bureau's website. For both methods, office building estimates provided in the CBECS report were adjusted for each size range based on assumptions about the average refrigerant charge size for the types of HVAC equipment presented in the report.

Data obtained from the CBECS report was more precise than facility number estimates obtained from the NAICS codes mapped from the Rule 1415 dataset because it provided a breakdown of office building categories by the types of HVAC equipment used. This enabled more accurate assignment of the proportion of office buildings assigned to each refrigerant charge size threshold.

Assumptions: Throughout the process of refining statewide estimates for individual R/AC refrigerant charge size categories it was necessary to make several assumptions. It was assumed that the facility number data provided in the ARMINES 2008 report are more accurate than the estimates obtained from the Rule 1415 dataset. This is likely to be the case because the food retail estimate from the Rule 1415 dataset could only be mapped to a very broad NAICS code representing almost all retail food establishments in California, including business types that do not normally use large R/AC equipment (e.g., butcheries, retail seafood stores, and bakeries). Additionally, the facility number estimates provided by the ARMINES 2008 report include only facility categories that were determined to use R/AC equipment within the small, medium, and large R/AC system thresholds (based on surveys and site visits conducted in California). The same assumption is applicable to pharmacy and hotel facility number estimates obtained from the ARMINES 2008 report.

It is assumed that the information obtained from ARB stakeholder feedback regarding the proportion of cold storage and food processing facilities that utilize ammonia and CO_2 as refrigerants provides an accurate representation of refrigerant use in California for these facility types. It is also assumed that the distribution of refrigerant charge sizes for chillers provided in the Rule 1415 dataset applies to all chillers in use in California. This distribution indicated that approximately 6% of chillers in use in California have refrigerant charge sizes greater than 2,000 lbs.

Finally, it was assumed that national data provided in the CBECS report, are accurate and provide a good starting point for extrapolation to California based on population size. It is possible that patterns of HVAC use by office buildings in the CBECS report do not accurately represent HVAC use by offices in California. Additionally, based on descriptions of the type of equipment (obtained from the CBECS report glossary) several assumptions regarding the distribution of refrigerant charge sizes within different HVAC category presented were necessary. These assumptions include: 1) “Packaged A/C unit” category represented medium sized HVAC units, 2) 94% of the “Central chiller” category were in the medium R/AC system threshold and 6% were in the large R/AC system threshold, and 3) the “district chilled water” category represented equipment in the large R/AC system threshold.

Independent verification and refinement of Rule 1415 data extrapolation to statewide facility numbers using CEUS Survey Data.

In addition to the above methodology used to extrapolate Rule 1415 facility numbers to statewide facility numbers, facility numbers and types; and system numbers and types were independently estimated using CEUS survey data provided by the California Energy Commission. The CEUS survey data was used to derive an independent approach to estimating the numbers of facilities and R/AC equipment in the state. The CEUS data was also used to refine emission factors that could be applied to all R/AC equipment in specific charge size categories.

In a few cases, CEUS results differed slightly (less than five percent) from Rule 1415 extrapolations, and the numbers and types of facilities (and R/AC systems) were refined and made more accurate where necessary.

Although the approach used to extrapolate CEUS data to statewide data was similar to the approach used for Rule 1415 data, the methodology was more streamlined due to the greater sampling area of CEUS data.

CEUS data for year 2007 was a sampling of commercial buildings in California that represented 85 percent of the state's population and regions. The sampled data was presented to ARB already extrapolated to the entire survey region and population (85 percent of the state). ARB staff further extrapolated the 85 percent coverage of the state to 100 percent coverage of the state by multiplying all data results (building numbers, R/AC equipment numbers) by 1.18, (or 100%/85%) to scale up to a 100 percent representation of state data.

The CEUS data included many data fields pertaining to commercial refrigeration and cooling systems. The following is a partial listing of fields applicable to the methodology used to estimate statewide refrigerant emissions:

- Numbers of facilities in California by broad business-type categories (categories corresponded to the NAICS business categories mapped to Rule 1415 facilities).
- Total number of facilities (in CEUS survey area representing 85% of state) by each business type.
- Number of facilities with specific types of R/AC equipment (single-zone DX units, multiple-zone DX units, remote refrigerated condensing units, chillers, HVAC systems [single-zone and multiple-zone]. and for specific retail food equipment [walk-in coolers/freezers, and multiple types of display cases,
- R/AC equipment numbers and average numbers per type of business facility.
- Tons of cooling capacity by type of equipment (converted to pounds refrigerant charge for the rule analysis).

The following shows the methodology used to estimate facility numbers and emissions factors using CEUS data.

1. Facility numbers were already presented by applicable business category, but were scaled from 85 percent to 100 percent of the state's population.
2. Numbers of R/AC equipment were similarly scaled up to represent the entire state.
3. Tons of cooling capacity shown for each piece of equipment were converted to pounds of refrigerant. The conversion factors used were 3.5 pounds refrigerant/ton cooling capacity for small and medium HVAC systems, and 5 pounds refrigerant/ton cooling capacity for all large equipment (cold storage, process cooling, centralized systems), and medium sized centralized cooling systems.
4. All R/AC equipment was then categorized into small, medium and large charge sizes.
5. Average number and types of systems per facility were calculated by charge size only. This average was additionally refined by using U.S. EPA Vintaging Model data to further use specific ratios of R/AC systems per broad charge category. For example, the small charge category consists only of unitary AC systems and refrigerated condensing units. The U.S. EPA Vintaging Model profiles show that nationally, 80 percent of these systems will be unitary AC systems and the remaining 20 percent will be refrigerated condensing units.
6. Refined number of facilities and R/AC systems were then re-applied to the basic emissions calculation formula.

Note that the CEUS survey did not contain any information on the specific type of refrigerant used or annual refrigerant usage (losses), so it was not used to refine emission factors such as average leak rates of systems.

Section 3. Assumptions used to assign Equipment Type to Rule 1415 Data

Where equipment type was not conclusive from Rule 1415 data, an equipment type was assigned based on the U.S. EPA Vintaging Model profiles for most likely equipment type given the type of business, refrigerant type, and refrigerant charge size (shown in the following table).

Table 11. Equipment type designations assigned for unclear reported data:

Aggregated Facility Category	Small Charge Category	Medium Charge Category	Large Charge Category
agricultural service	unitary A/C	cold storage	N/A
airport	unitary A/C	chiller	N/A
amusement/recreation parks	unitary A/C	chiller	centrifugal chiller
beer and ale	unitary A/C	cold storage	N/A
bottled gas dealers	unitary A/C	chiller	N/A
cemeteries/crematories	unitary A/C	chiller	N/A
dairy	unitary A/C	cold storage	cold storage
department stores	unitary A/C	chiller	centrifugal chiller
education - K - 12	unitary A/C	chiller	centrifugal chiller
education - Junior college	unitary A/C	chiller	N/A
education - tech and trade schools	unitary A/C	N/A	N/A
education - universities	unitary A/C	chiller	centrifugal chiller
food processing	unitary A/C	cold storage	cold storage
fresh fruit and vegetable wholesale	unitary A/C	cold storage	cold storage
frozen food wholesale	unitary A/C	cold storage	cold storage
fruit and vegetable processing	unitary A/C	cold storage	N/A
hotels/motels	unitary A/C	chiller	centrifugal chiller
ice manufacturing	unitary A/C	N/A	N/A
libraries	unitary A/C	chiller	N/A
manufacturing (non-food)	unitary A/C	chiller	chiller
meat processing	unitary A/C	cold storage	cold storage
medical care	unitary A/C	chiller	centrifugal chiller
misc warehousing/storage	unitary A/C	chiller	centrifugal chiller
museums	unitary A/C	chiller	N/A
office buildings	unitary A/C	chiller	centrifugal chiller
petroleum	unitary A/C	chiller	centrifugal chiller
pharmacies	refrig: small - medium units	chiller	N/A
publishing	unitary A/C	chiller	centrifugal chiller
refrigerated warehousing/storage	unitary A/C	cold storage	cold storage
religious organizations	unitary A/C	chiller	N/A
research and development	unitary A/C	chiller	N/A
retail (food)	refrig: small - medium units	refrig: centralized system	refrig: centralized system
retail (non-food)	unitary A/C	chiller	centrifugal chiller
semiconductor	unitary A/C	chiller	process cooling
service industry	unitary A/C	chiller	centrifugal chiller
telecommunications	unitary A/C	chiller	N/A
TV/movie production	unitary A/C	chiller	centrifugal chiller
utilities	unitary A/C	chiller	centrifugal chiller
wholesale - (non-food)	unitary A/C	chiller	centrifugal chiller